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The Effect of Hovering Flares on Visual Target Acquisition

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FOREWORD

This technical report documents work conducted from January to October 1974 at Wright-Patterson Air Force Base, Ohio and at the Naval Weapons Center, China Lake, Calif., as part of a joint services program on air-to-ground target acquisition funded under authorization ARAB RA 05-75.

The Joint Technical Coordinating Group for Munitions Effectiveness has established a Target Acquisition Working Group (TAWG) under the Joint Munitions Effectiveness Manual/Air-to-Surface Division. TAWG tasks have included the definition of problem areas in airborne forward air controller operations, the description of target markers, summary of existing field test data, the evaluation of mathematical models of target acquisition, the camouflage of targets, terrain and foliage masking, and research on target acquisition by flare light.

This report presents the description and results of a flare experiment that was conducted on a terrain model at the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base. Part of the data analysis and the report preparation was performed at the Naval Weapons Center.

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(U) *The Effect of Hovering Flares on Visual Target Acquisition*, by MAJ Robert L. Hilgendorf and S/SGT Robert G. Searle, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, and Ronald A. Erickson, Naval Weapons Center, China Lake, Calif., Naval Weapons Center, January 1975, 12 pp. (NWC TP 5722, publication UNCLASSIFIED.)

(U) A laboratory experiment was conducted on a terrain model to assess the effect of a hovering flare on target acquisition performance. One group of subjects was asked to search for targets of opportunity by the light of two hovering flares. Another group searched with two normally descending flares. The hovering flare group found 59% of the targets as compared to 52% by the descending flare group. Although this difference is statistically significant, its operational significance is open to question. The data are shown to be directly related to the area on the ground illuminated by 0.2 footcandle.

CONTENTS

INTRODUCTION

A joint-services Target Acquisition Working Group (TAWG) was established in March 1972 and tasked with pursuing a number of studies of visual, air-to-ground target acquisition. Target acquisition by flare light was one of the areas addressed; a summary report was issued,[1] and three laboratory experiments were conducted on a terrain model.

These experiments were conducted to provide data on possible flare characteristics for use by flare designers. The areas addressed were the possible enhancement of target acquisition performance by (1) a flare stabilized against wind effects,[2] (2) a choice of color of flare light (to be published), and (3) a hovering flare.

This report describes the experiment on a hovering flare and discusses the results in terms of applicability in flare design.

BACKGROUND

The area of ground illuminated to some specified level by a flare is a function of the luminous intensity of the flare and its altitude above the ground. Laswell[3] developed a family of curves showing this ground area-flare altitude relationship for a threshold illumination level of 0.2 footcandle (the 0.2 footcandle value has been used as an "optimal" illumination level by flare developers). A plot of Laswell's relationship is shown in Figure 1 for a 2-million candlepower flare. It is seen that the flare provides a maximum area illuminated by 0.2 footcandle or greater when it is at 1,500 ft above the ground.

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[1] Aerospace Medical Research Laboratory, Wright-Patterson AFB. *Flare Effectiveness Factors: A Guide to Improved Utilization for Visual Target Acquisition*, by Sheldon MacLeod. Dayton, Ohio, AMRL, November 1973. (AMRL-TR-73-46, publication UNCLASSIFIED.)

[2] ------. *The Effect of Flare Drift on Target Acquisition Performance*, by Russell A. Sorensen. Dayton, Ohio, AMRL, 1974. (AMRL-TR-74-73, publication UNCLASSIFIED.)

[3] Naval Ammunition Depot. *Study of the Optimum Suspension of a High Intensity Parachute Flare*, by J. E. Laswell. Crane, Indiana, NAD, May 1963. (RDTN No. 30, publication UNCLASSIFIED.)

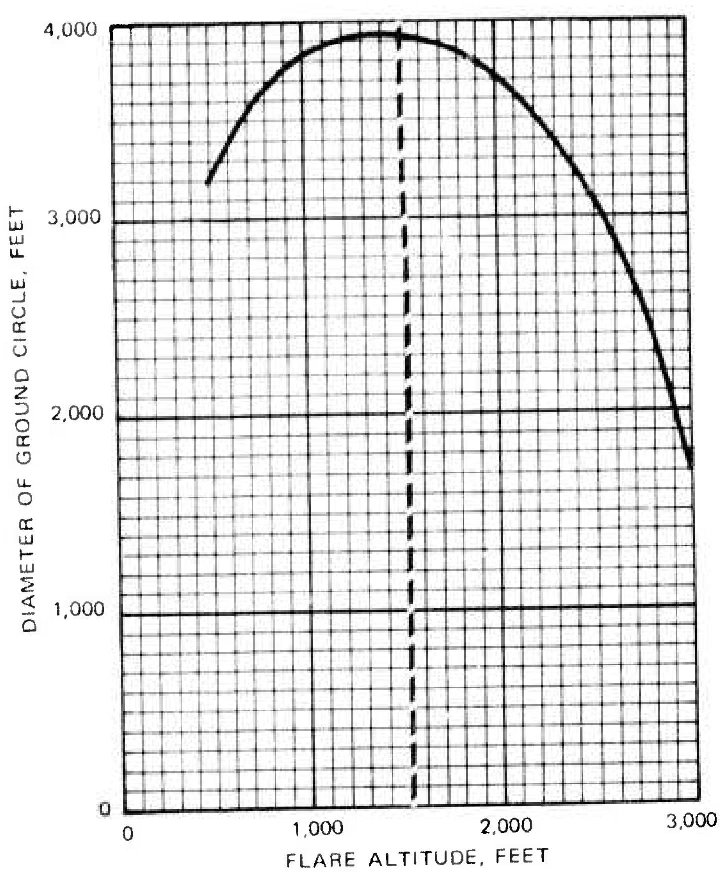

FIGURE 1. Ground Area Illuminated by at Least 0.2 Footcandles from a 2-Million Candlepower Flare.

Hilgendorf[4] has shown in a terrain model experiment that it takes about twice as long to detect targets when they are outside this 0.2-footcandle ring (search time was 1 min inside versus 2 min outside). If a flare is ignited at 2,400 ft and burns out at 500 ft, the circle illuminated by 0.2 footcandle varies from 3,200 ft diameter to a maximum of 4,000 ft and back down to 3,200 ft; the 4,000-ft circle has 1.6 times the area as the 3,200-ft circle.

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[4] Aerospace Medical Research Laboratory, Wright-Patterson AFB. *Visual Search and Detection Under Simulated Flarelight*, by Robert L. Hilgendorf. Dayton, Ohio, AMRL, August 1968. (AMRL-TR-68-112, publication UNCLASSIFIED.)

With these relationships and experimental results in mind, the question arose as to the possible advantage of a flare that could hover at the "optimal" altitude throughout its burning time.

This report describes an experiment where target acquisition performance for targets-of-opportunity was measured for a normally descending flare and a hovering flare. It was hypothesized that the hovering flare would lead to better search performance than the descending flare. The results are useful in assessing the advantages in a hovering flare.

METHOD

Subjects were required to search by flare light for scale model targets located on a model of Central European-type terrain. Flares over the terrain were simulated by suspending small lightbulbs above the terrain, and moving them as required to simulate descent and wind drift. The subjects were "flown" by the terrain at a simulated altitude of 2,000 ft and velocity of 100 knots by a chair-transport mechanism. Their responses were used to compute the mean number, or percent of the targets detected, and the number of errors made.

SUBJECTS

The subjects were 20 male college students with normal color vision and 20/20 or better far and near visual acuity. Color vision was tested by the Dvorine Pseudo-Isochromatic Plates and visual acuity testing was accomplished by the Bausch and Lomb Master Ortho-Rater.

DESIGN

The subjects were divided into two groups of ten subjects each. One group performed with the simulated flares descending normally and the other with the flares stabilized at the "optimal" altitude. This resulted in two groups whose performance data were suitable for testing for statistical significance with the Student $\underline{t}$ distribution. The dependent variables were number of targets acquired and errors.

APPARATUS

Flares

The LUU-2B/B was the flare simulated in this experiment. This flare produces 2-million candlepower for approximately 4 min with an average descent rate of 7.2 ft/sec.[5] Simulation of the flare was accomplished by using a standard No. 47 pilot lamp, but operated 9 volts instead of 6. At this voltage, the lamp produces the proper intensity which simulates 2-million candlepower at a scale of 1:1,000.[6] To simulate the flare descent, the lamps were mounted on a mechanically driven, electronically controlled framework. Two simulated flares were used and they were separated by 5.28 ft simulating a distance of about 1 mile. The flares were ignited in such a way to simulate a flare aircraft flying a track parallel to the flight path of the subject and along the longitudinal axis of the terrain model (Figure 2). An earlier study had demonstrated this deployment concept for the area which was simulated by the terrain model.[7] The descent of each flare was controlled by a 28-volt DC motor. The voltage to each motor is a ramp function to simulate the constantly decreasing velocity in the descent of a parachute flare due to its loss of mass and also due to its heat generation while burning. In addition, a 24-volt DC motor was installed on the descent framework of each flare to provide simulated flare drift due to wind. For the descending condition, the flares were set to ignite at a simulated altitude of 2,400 ft above ground level (AGL) and to burn out at a simulated altitude of 500 ft AGL. Under the fixed condition, the altitude of the flare was maintained at a simulated 1,500 ft. A wind drift of 5 knots was also simulated for both conditions.

Terrain Model

The terrain model, over which the subjects searched for targets, is on a scale of 1:1,000 and provides a reasonably realistic portrayal of Central European terrain. Its dimensions (5 ft x 18 ft) represent a terrain strip approximately 3 miles long by 1 mile wide. The model simulates the color and reflectance properties of the real world within the visible portion of the electromagnetic spectrum and contains a river, road, bridge, and foliage (Figure 3).

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[5] Eglin Air Force Base. *Functional Test of the LUU-2B/B Aircraft Flare*, by B. G. Ernst. Eglin AFB, Florida, ADTC, April 1970. (ADTC-TR-70-100, publication UNCLASSIFIED.)

[6] North Atlantic Treaty Organization. *Air-to-Ground Target Acquisition with Flare Illumination*, by Robert L. Hilgendorf. AGARD Proceedings No. 100 in Air-to-Ground Target Acquisition, Brussels, Belgium, 1972 (pp. B9–1 to B9–10).

[7] United States Air Force Academy. *Current Research in Simulated Battlefield Illumination: Effects of Flare Shielding*, by Robert L. Hilgendorf. Proceedings of the 2nd Annual Symposium of Psychology in the Air Force. Denver, Colorado, 1970 (pp. 282–295).

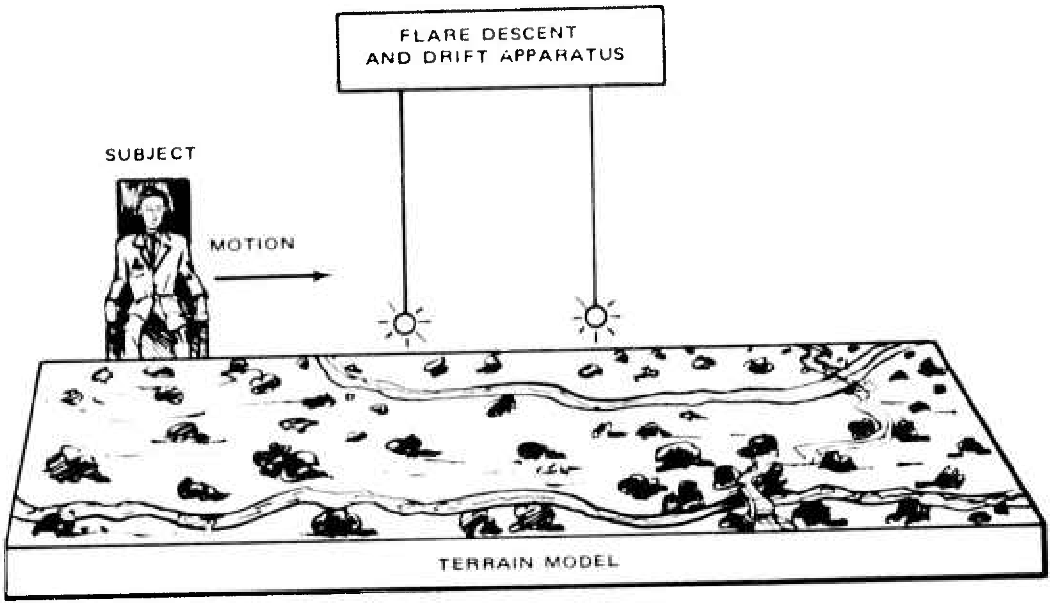

FIGURE 2. Sketch of Terrain Model and Apparatus.

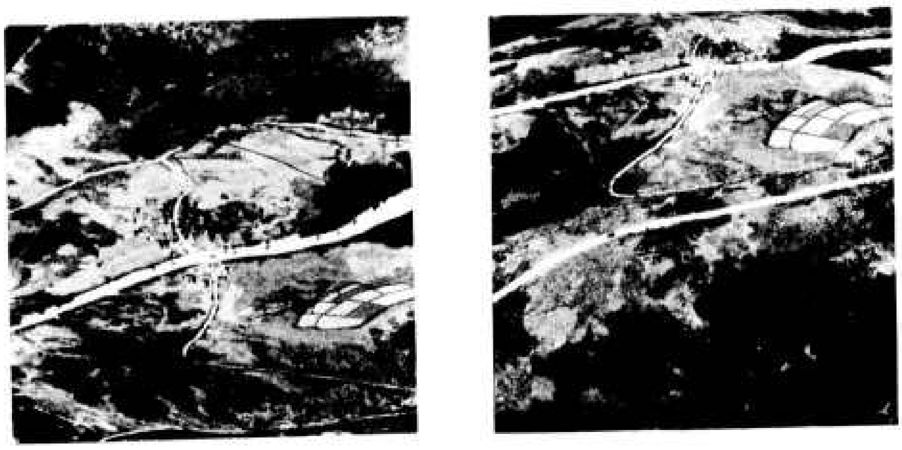

FIGURE 3. Views of Parts of the Terrain Model Used in the Study.

Subject Transport Mechanism

A motorized optometrist's chair was used to "fly" the subject along (beside) the terrain model. The subject wore a helmet with a lock feature, such that the back of the helmet was fixed against the chair's head pads. Through the use of the chair's elevation feature, the eye level of each subject was maintained at a mean of 24 inches above the terrain model's surface to correspond to a simulated altitude of 2,000 ft. Selection of this altitude was based upon a previous study which showed that target acquisition from 2,000 ft was easier than from higher altitudes.[8] The chair was placed on a motorized trolley which propelled the subject along the terrain model at a simulated speed of about 100 knots.

The nondominant eye of each subject was covered by an eye patch to simulate the absence of stereovision, since at the actual ranges which were simulated, there would be no stereoscopic distance/depth cues available.

Targets

The targets were a river, a road, a bridge, a parked truck, a moving truck, a moored boat on the river, a moving boat, and three single tanks. The moving boat and truck were always started from their respective starting points and moved at velocities of 40 mph and 15 knots, respectively. The vehicles and boats were isolated from one another so that there were seven point targets, two of them moving.

PROCEDURE

After initial visual screening and preliminary explanation, each subject was trained to identify the targets listed above. This training was accomplished on a smaller terrain model located in the subjects' preparatory room.

The subject was then brought into the test room, seated, and allowed to adapt to the dark for 15 min. During this time, the instructions were repeated and the subject was asked to name the targets for which he would be looking.

During the actual run, the subject was asked to call out the name of each target as he sighted it. Due to the high learning rate associated with targets on the terrain model, each subject was used for only one experimental trial.

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[8] Hilgendorf, R. L., "Visual Performance with Simulated Flare Light: Effects of Flare-Ignition Altitude," HUMAN FACTORS, Vol. 13, No. 4, 1971, pp. 379–386.

The total number of valid targets found (detected, identified, and located) by each subject and the number of errors (e.g., identifying a truck when there was none in the area) were recorded for each subject. In addition, the time of his report was noted (with t = 0 being the start of the trial); this time could be correlated with his location along the terrain model.

RESULTS AND DISCUSSION

Three of the ten targets do not provide any data on differences between search by the hovering and descending flares. The river was reported by all subjects in both groups. Two tanks were never seen by any of the subjects. Performance on the individual targets is shown in Table 1. The performance of the individual subjects across all 10 targets is shown in Table 2.

The hovering flare group found more targets than the descending flare group (59 versus 52); this difference was found to be statistically significant by a t-test for independent means ($t = 1.87$; $p > 0.05$). Both groups committed about the same number of errors: 10 for the hovering flare group and 11 for the descending flare group.

In summary, the results of this experiment did show that more targets were found by the light of two flares hovering at the optimal altitude than by the light of two normally descending flares.

The results of this experiment can be related to the lighting geometry of Figure 1. The produce of (1) the area lighted by at least 0.2 footcandle and (2) the duration of illumination gives one value of the area-time available for search. For one hovering flare, this product is 12×10^6 sq. ft x 4 min, or 48 million sq. ft-min. For a descending flare, the integral of area-time yields about 42 million sq. ft-min or 0.9 of the hovering flare. The subjects found 52 targets by the descending flares, or about 0.9 of the number they found by the hovering flares.

Although two flares were used in this experiment, their 0.2-footcandle circles did not overlap since they were separated by 1 mile. It also should be pointed out that 0.2 footcandle is not a magic number; it was selected rather arbitrarily after some theoretical deliberations, and has only been used as a boundary in one experiment (see Footnote 4). Nevertheless, this experiment has indicated that the area illuminated by at least that level is related to target acquisition performance.

The data tend to support the contention that the hovering flare concept is associated with superior search performance. The practical or operational significance of the results poses another question. Whether or not this performance increase (13% more targets found in this experiment) is great enough to justify development of a hovering flare is a consideration which should be addressed by armament developers.

TABLE 1. Percent of the Ten Subjects From Each Group That Found a Valid Target.

Target	Percent targets found	
	Group with hovering flares	Group with descending flares
River	100	100
Road	90	100
Bridge	70	100
Moving boat	90	100
Parked truck	90	60
Moored boat	90	50
Moving truck	50	10
Tank	10	0
Tank	0	0
Tank	0	0
Average across all targets	59	52

TABLE 2. Number of Valid Targets Located by Each Subject (Ten Targets Possible).

Hovering flare group	Descending flare group
7	5
5	4
7	5
6	6
6	5
7	5
6	5
4	5
5	6
6	6
Mean 5.9	5.2
SD 1.0	0.6

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